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November 2, 1990

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FROM: Dr. David K. Ferry  
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SUBJECT: Final Report, Award Number N00014-90-J-1757

Enclosed please find a copy of the Final Report in accordance with the terms of the agreement for the Grant to support the *Physics of Cellular Automata and Quantum Dots Workshop*.

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Final Report  
Cellular Automata and Quantum Dots  
An Office of Naval Research Workshop

The purpose of the workshop was to bring together a select group of physicists and computer scientists to discuss methods of domesticating quantum "dots" for computational purposes. There are a variety of ways of constructing with modern lithography two-dimensional arrays of these quantum dots, in which the individual dots can range from simple quantum wells to sophisticated resonant tunneling devices. In each case, the arrays to date have been limited to two dimensions, or planar technology. Cellular automata provide a computing paradigm where uniform arrays with local interconnections can be made to yield general purpose computation in a reasonably compact way.

One of the main technological challenges is that we are abandoning the security of the law of large numbers (say 1,000,000 electrons per bit) and we are not yet capable of controlling fabrication at the level of one or a few atoms. As a consequence, structures today are being made in the so-called mesoscopic regime and future fabrication technology must traverse a high dispersion regime, in which fluctuations in device parameters are bound to significantly affect architectural policies.

Cellular automata provide a variety of different schemes, some of which may be suitable for certain implementations of quantum dot

arrays. However, insufficient cross-fertilization of the two fields has occurred to date for any significant recognition of the prospective applications or the proper routes to technological development of systems. Consequently, it is not clear whether the most promising routes are those yielding general purpose architectures or alternatives oriented at special purpose, massive computation engines for more unique applications.

On the other hand, both disciplines seem to be sufficiently mature and to offer a significantly wide range of concepts and tools such that a match between some concepts and tools of the two disciplines seems feasible. This was brought forth from the many remarks and the discussions. The workshop was successful in achieving cross-fertilization between the two fields. Many promising routes for future research were discussed, and a number of significant issues were identified. In addition, valuable contacts between various individuals and laboratories were established. Some of the major issues that were identified during the workshop are:

1. If this field is to reach fruition, development of device and architectural concepts cannot continue separately, and a merging of these concepts must be made in future work.
2. Several possible modes of storage in quantum dots have been demonstrated, but modes of inter-dot coupling are still in a very primitive stage. It is clear that significant development work in

this latter area is necessary, guided by the requirements of a target architecture.

3. While massive throughput in quantum dot arrays seems possible, the issue of massive input/output has barely been touched. On the other hand, since many useful computations require only a modest amount of input/output, it is not vital to solve this question at once. Rather, it is possible that schemes in which information is fed in from the boundaries may be quite useful and are more readily implementable in the near term.

4. Most current efforts in the study of quantum dots have focused on near equilibrium properties to reach a basic understanding; e.g. low temperatures and small applied potentials. For more realistic computational usage, these structures will need to be used in a far from equilibrium mode, at high temperatures. This means that considerable work must be done in order to gain understanding of the properties of these arrays under these conditions.

5. Present studies of quantum dots have centered on material systems in which the quantum effects are more easily seen. It is not clear if these materials are suited to volume production of quantum dot computational arrays operating at room temperature. More understanding of the materials properties required is needed.

6. Nanostructure technology must also be advanced, so that size scales may be reduced to achieve quantum confinement energies

suitable for room temperature operation.

7. Cross-fertilization between computational science and quantum dot physics, initiated with this workshop, needs to be continued.

8 June 1990

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